BACTERIAL-DERIVED MOLECULES AND THERAPEUTIC AND DIAGNOSTIC USES THEREFOR

FIELD OF THE INVENTION

The present invention relates generally to molecules derived from a *Mycobacterium* species and recombinant, synthetic, derivative, homologue and analogue forms of said molecules. The molecules of the present invention are useful in diagnostic assays for *Mycobacterium* in biological and environmental samples. The present invention is particularly directed to molecules derived from *Mycobacterium tuberculosis* and related organisms and even more particularly to recombinant forms of these molecules or synthetic, derivative, homologue or analogue forms thereof and their use in diagnostic and therapeutic protocols for tuberculosis or other disease conditions associated with *M. tuberculosis* or related organisms.

BACKGROUND OF THE INVENTION

Bibliographic details of the publications numerically referred to in this specification are collected at the end of the description.

Bacterial infection represents a major cause of mortality and morbidity in human and other animal populations. One important group of bacteria are the mycobacteria. The mycobacteria are defined on the basis of a distinctive staining property conferred by their lipid-rich cell walls. The mycobacteria are relatively impermeable to various basic dyes but once stained, they retain dyes with tenacity. The mycobacteria have been referred to as "acid-fast" bacteria since they resist decolorization with acidified organic solvents (1). Mycobacteria range from widespread innocuous inhabitants of soil and water to organisms responsible for devastating and chronic diseases notably in tuberculosis and leprosy caused by *Mycobacterium tuberculosis* and *Mycobacterium leprae,* respectively.

Leprosy involves infection in skin tissue and can lead to disfigurement. Tuberculosis is generally confined to internal organs. Although both leprosy and tuberculosis were largely controlled by chemical intervention and improvements in living conditions, tuberculosis is now re-emerging as a major health problem. On an annual basis, reportedly between 2 and 3 million people die from tuberculosis, mostly in developing countries (2).

Conventional diagnostic tests for tuberculosis include chest X-ray, detecting the presence of acid-fast bacilli in clinical specimens and the skin test using tuberculin PPD (Purified Protein Derivative) [3]. However, these procedures are time intensive, frequently the results are ambiguous and X-ray machines are expensive and generally not portable enough for use in developing countries.

Nucleic acid probes can be used in a polymerase chain reaction (PCR) to specifically detect a mycobacterial infection, but require complex equipment, highly skilled staff and are too expensive for the developing countries (4). Rapid serological diagnostic tests are available on an ELISA or "strip" format which uses antigen(s) to detect antibody in sera (5). However, currently there is no satisfactory test for tuberculosis. A majority of *M. tuberculosis* antigens studied to date have homology with analogues proteins of other microorganisms that may or may not be pathogenic; resulting in cross-reactivity of these antigens to reactive serum antibodies in patients with inactive TB or nontuberculous infections (6). Hence, positive test results produced by these known antigens are generally unreliable and supplementary tests are required to confirm the presence of the tuberculosis infection.

In work leading up to the present invention, the inventors sought to use recombinant molecules from *M. tuberculosis* in the development of a highly specific and sensitive diagnostic test for tuberculosis. The same or similar molecules are also proposed for use as therapeutic agents for the treatment of tuberculosis.

SUMMARY OF THE INVENTION

Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element or integer or group of elements or integers but not the exclusion of any other element or integer or group of elements or integers.

The subject specification contains nucleotide and amino acid sequence information prepared using the programme PatentIn Version 2.1, presented herein after the bibliography. Each

nucleotide or amino acid sequence is identified in the sequence listing by the numeric indicator <210> followed by the sequence identifier (e.g. <210>1, <210>2, etc). The length, type of sequence (DNA, protein (PRT), etc) and source organism for each nucleotide or amino acid sequence are indicated by information provided in the numeric indicator fields <211>, <212> and <213>, respectively. Nucleotide and amino acid sequences referred to in the specification are defined by the information provided in numeric indicator field <400> followed by the sequence identifier (eg. <400>1, <400>2, etc).

One aspect of the present invention provides an isolated polypeptide or a derivative, homologue, analogue or functional equivalent thereof wherein said polypeptide is obtainable from a species of *Mycobacterium* and which polypeptide is immunointeractive with sera from a human, animal or avian species exposed to said species of *Mycobacterium* or its relative or antigenic parts thereof but which polypeptide is substantially not immunointeractive with sera from a human, animal or avian species not prior exposed to said species of *Mycobacterium* or its relative or its antigenic parts.

Another aspect of the present invention is directed to an isolated polypeptide or a derivative, homologue, analogue or functional equivalent thereof wherein said polypeptide is obtainable from *M. tuberculosis* or a related organism and which polypeptide is immunointeractive with sera from a human previously exposed to *M. tuberculosis* or an antigenic extract therefrom but is substantially not immunointeractive with human sera not previously exposed to *M. tuberculosis* or a antigenic extract thereof.

Yet another aspect of the present invention relates to an isolated polypeptide obtainable from *M. tuberculosis* or related organism or a derivative, homologue, analogue or chemical equivalent of said polypeptide which polypeptide is immunointeractive with sera from a human patient with active pulmonary or extra-pulmonary tuberculosis but is substantially not immunointeractive with sera from a subject not previously infected with *M. tuberculosis* or sera from a subject who otherwise has no immunological memory for said polypeptide or antigenic derivatives thereof.

Still yet another aspect of the present invention provides a polypeptide having a molecular weight selected from about 5 kDa to about 100 kDa or a derivative, homologue, analogue or

functional equivalent thereof said polypeptide obtainable from *M. tuberculosis* and wherein polypeptide is immunointeractive with sera from a patient with active pulmonary or extra-pulmonary tuberculosis but substantially not immunointeractive with sera from a subject who does not have active pulmonary or extra-pulmonary tuberculosis.

In still yet another aspect of the present invention there is provided a polypeptide having a molecular weight selected from about 10 to 20 kDa, 28 to 38 kDa, 38 to 48 kDa, 53 to 63 kDa and 55 to 65 kDa or a derivative, homologue, analogue or functional equivalent thereof said polypeptide obtainable from *M. tuberculosis* and wherein polypeptide is immunointeractive with sera from a patient with active pulmonary or extra-pulmonary tuberculosis but substantially not immunointeractive with sera from a subject who does not have active pulmonary or extra-pulmonary tuberculosis.

Yet a further aspect of the present invention provides a polypeptide comprising an amino acid sequence selected from <400>2, <400>4, <400>6, <400>8, <400>10 or an amino acid sequence having at least 60% similarity to any one of said sequences.

Still yet a further aspect of the present invention provides a polypeptide encoded by a nucleotide sequence selected from <400>1, <400>3, <400>5, <400>7, <400>9 or an nucleotide sequence having at least 60% similarity to any one of said sequences or a nucleotide sequence capable of hybridizing to any one of said sequences under low stringency conditions at 42°C.

Another aspect of the present invention contemplates a method of isolating a polypeptide from *Mycobacterium* species said method comprising culturing cells of said *Mycobacterium* species in a growth medium to increase the number of cells to a sufficient population, harvesting said cells and subjecting said cells to protein extraction techniques to extract protein from said cells, fractionating the extracted protein and subjecting said protein to binding analysis with antibodies to said *Mycobacterium* species or antigenic portions thereof and isolating the polypeptides to which antibodies interact.

Yet another aspect of the present invention is directed to an isolated nucleic acid molecule comprising a sequence of nucleotides encoding or complementary to a sequence encoding a

polypeptide obtainable from a species of *Mycobacterium* and which polypeptide is immunointeractive with sera from a human, animal or avian species exposed to said species of *Mycobacterium* or its relative or antigenic parts thereof but which polypeptide is substantially not immunointeractive with sera from a human, animal or avian species not prior exposed to said species of *Mycobacterium* or its relative or its antigenic parts.

Another aspect of the present invention contemplates a method for detecting the presence of *M. tuberculosis* such as in a patient suffering from tuberculosis said method comprising contacting a biological sample from a patient or subject with an antibody specific for a polypeptide from said *M. tuberculosis* and detecting a complex between said polypeptide and said antibody.

Yet another aspect of the present invention provides a method for detecting the presence of *M. tuberculosis* such as in a patient suffering from tuberculosis said method comprising contacting a sera sample from a patient or subject with a polypeptide from *M. tuberculosis* and detecting a complex between said polypeptide and an antibody in said sera.

Still yet another aspect of the present invention provides an assay device for *M. tuberculosis* comprising a solid support having immobilized thereon one or more polypeptides obtainable from *M. tuberculosis* or derivatives, homologues, analogues or antigenic equivalents thereof and a portion of said solid support adapted for receiving a sample from a human subject to be tested wherein said sample would contain an antibody specific for said *M. tuberculosis* polypeptide if said subject has been exposed to *M. tuberculosis* wherein upon contact between the antibody from the subject and the immobilized polypeptide, a complex forms and said complex is detected by an anti-human immunoglobulin labelled with a reporter molecule.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a diagrammatic representation of the strategy for the isolation and expression of *M. tuberculosis* protein antigens.

Figure 2 is a photographic representation showing (A) gel purified and concentrated *M. tuberculosis* protein bands (B.1, 2, 3, 4, 5, 6, 8, 9, 10) blotted onto PVDF membrane and were then excised for N-terminal sequencing; (B) concentrated *M. tuberculosis* protein bands were

blotted onto nitrocellulose membrane and immuno-screened using pooled normal (N) and active (A) sera, respectively. Positive bands (arrows) were observed with A but not with N.

Figure 3 is a representation showing the results of homology search against the GenBank protein sequence databases. Proteins showing the highest homology to the *M. tuberculosis* protein bands are as shown.

Figure 4 is a photographical representation of Western blot screening of recombinant *M. tuberculosis* antigens. (A) Arrows indicate the position of the recombinant antigens on the membrane. M=Kaleidoscope protein marker and H=strip probed with anti-RGSHis, C= a positive control of strips probed with known human serum reactive to the specific recombinant antigen. (B) Reactivity is estimated based on the intensity of the band.

Figure 5 is a representation of the percentage of reactivity of recombinant TB antigens against different sera panels. A known 38kDa antigen (7, 8) of *M. tuberculosis* was included in the screening. The gene (GeneBank Accession # M30046) for this antigen was cloned, expressed in pQE30 and partially purified. Also shown are the percentages of reactivity of sera samples detected by a commercially available rapid TB diagnostic kit from ICT (Amrad).

Figure 6 is a graphical representation of a result from a Western screen using sera from normal individuals or patients with extrapulmonary tuberculosis, pulmonary tuberculosis and inactive tuberculosis.

Figure 7 is a graphical representation showing the percentage of reactivity for various combinations of these recombinant antigens against the inactive, active (pulmonary) and active (extra-pulmonary) sera panels respectively.

Figure 8 is a graphical representation showing the comparison of reactivity against the different sera panel for the combination of all the recombinant TB antigens compared to the ICT TB diagnostic kit. The graph shows that the percentage of reactivity for the active sera panel (pulmonary and extra-pulmonary) is higher than that observed for the kit.

Figure 9 is a graphical representation showing that the combination of antigens (B.6 + B.10 + MMP + 38 kDa) gave a sensitivity (60-70%) higher than that observed for the ICT kit (50%).

A summary of the sequence listing is shown below:

Sequence	**Sequence Identity No.**
Nucleotide sequence of antigen B.4	<400>1
Amino acid sequence of antigen B.4	<400>2
Nucleotide sequence of antigen B.6	<400>3
Amino acid sequence of antigen B.6	<400>4
Nucleotide sequence of antigen B.10	<400>5
Amino acid sequence of antigen B.10	<400>6
Nucleotide sequence of antigen MMP	<400>7
Amino acid sequence of antigen MMP	<400>8
Nucleotide sequence of antigen C17	<400>9
Amino acid sequence of antigen C17	<400>10

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is predicated in part on the identification of molecules from *Mycobacterium* species which are immunointeractive with antigen-specific molecules from humans, animals or birds which have been infected with the *Mycobacterium* species or its relative or extracts thereof or following administration to humans, animals or birds the molecule itself or in combination with a mixture of molecules. Detection of the molecules from *Mycobacterium* species or antibodies thereto is indicative of the presence of the particular species of *Mycobacterium* and hence has both diagnostic and therapeutic implications.

Accordingly, one aspect of the present invention provides an isolated polypeptide or a derivative, homologue, analogue or functional equivalent thereof wherein said polypeptide is obtainable from a species of *Mycobacterium* and which polypeptide is immunointeractive with sera from a human, animal or avian species exposed to said species of *Mycobacterium* or its relative or antigenic parts thereof but which polypeptide is substantially not immunointeractive with sera from a human, animal or avian species not prior exposed to said species of *Mycobacterium* or its relative or its antigenic parts.

For the purposes of exemplifying the present invention, the preferred species of *Mycobacterium* is *M. tuberculosis*. However, the present invention also extends to its relatives, *Mycobacterium bovis* and *Mycobacterium africanum*. In addition, the present invention further contemplates other mycobacteria including but not limited to *Mycobacterium avium, Mycobacterium microti, Mycobacterium leprae, Mycobacterium lepraemurium, Mycobacteria paratuberculosis, Mycobacterium ulcerans, Mycobacterium marinum, Mycobacterium smegmatis, Mycobacterium intracellulare, Mycobacterium xenopi, Mycobacterium chelonei, Mycobacterium fortuitum, Mycobacterium farcinogenes, Mycobacterium flavum, Mycobacterium haemophitum, Mycobacterium kansasii, Mycobacterium phlei, Mycobacterium scrofulaceum, Mycobacterium senegalense, Mycobacterium simiae, Mycobacterium thermoresistible,* and *Mycobacterium xenopi*. Accordingly, in a preferred embodiment, the present invention is directed to an isolated polypeptide or a derivative, homologue, analogue or functional equivalent thereof wherein

said polypeptide is obtainable from *M. tuberculosis* or a related organism and which polypeptide is immunointeractive with sera from a human previously exposed to *M. tuberculosis* or an antigenic extract therefrom but is substantially not immunointeractive with human sera not previously exposed to *M. tuberculosis* or a antigenic extract thereof.

In the comparison to human sera not previously exposed to *M. tuberculosis,* this does not exclude sera from subjects previously exposed to other species of *Mycobacterium* or other genera having biochemical or genetic but not epidemeological properties related to *M. tuberculosis.*

The sera preferably contains antibodies to the polypeptide of the present invention. The present invention extends, however, to other antigen-specific molecules or components of the immune system having antigen specificity including but not limited to cells carrying surface immunoglobulins specific to the polypeptide and T-cell derived antigen binding molecules (TABMs).

Preferably, the immunointeraction is an interaction between an antibody in the sera of a person previously exposed to *M. tuberculosis* or a related organism or an antigen containing extract therefrom and the polypeptide or its antigenic derivatives from *M. tuberculosis.* The term "related" in this context means another species of *Mycobacterium* or strain of *M. tuberculosis* which is associated with a similar disease as caused or exacerbated by *M. tuberculosis.*

Generally, a person "previously" exposed to *M. tuberculosis* or its antigen extract, is a person exhibiting immunological memory of the interaction and, hence, carrying antibodies in the sera to an antigen of *M. tuberculosis.* Conveniently, the sera are from patients with active pulmonary or extra-pulmonary tuberculosis.

As stated above, reference to a relative to *M. tuberculosis* includes various strains of *M. tuberculosis* as well as different species of *Mycobacterium* which contain the same polypeptide or an antigenically related polypeptide. Examples of related species include *M. bovis* and *M. africanium.* Such related strains or species would induce or be associated with similar disease conditions induced by *M. tuberculosis.*

Accordingly, another aspect of the present invention provides an isolated polypeptide

obtainable from *M. tuberculosis* or related organism or a derivative, homologue, analogue or chemical equivalent of said polypeptide which polypeptide is immunointeractive with sera from a human patient with active pulmonary or extra-pulmonary tuberculosis but is substantially not immunointeractive with sera from a subject not previously infected with *M. tuberculosis* or sera from a subject who otherwise has no immunological memory for said polypeptide or antigenic derivatives thereof.

In a preferred embodiment, the polypeptides of the present invention from *M. tuberculosis* range in molecular weight from about 5 kDa to about 100 kDa. More preferably, the polypeptides have a molecular weight range of from about 10 to 20 kDa, 28 to 38 kDa, 38 to 48 kDa, 53 to 63 kDa and 55 to 65 kDa.

In a most preferred embodiment, the molecular weight of the polypeptides are selected from 16±3, 33±3, 38±3, 55±3 and 56±3 kDa.

Accordingly, another aspect of the present invention is directed to a polypeptide having a molecular weight selected from about 5 kDa to about 100 kDa or a derivative, homologue, analogue or functional equivalent thereof said polypeptide obtainable from *M. tuberculosis* and wherein the polypeptide is immunointeractive with sera from a patient with active pulmonary or extra-pulmonary tuberculosis but substantially not immunointeractive with sera from a subject who does not have active pulmonary or extra-pulmonary tuberculosis.

More particularly, the present invention provides a polypeptide having a molecular weight selected from 16±3, 33±3, 38±3, 55±3 and 56±3 kDa or a derivative, homologue, analogue or functional equivalent thereof said polypeptide obtainable from *M. tuberculosis* and wherein polypeptide is immunointeractive with sera from a patient with active pulmonary or extra-pulmonary tuberculosis but substantially not immunointeractive with sera from a subject who does not have active pulmonary or extra-pulmonary tuberculosis.

The present invention is particularly exemplified in relation to *Mycobacterium* antigens B.4, B.6, B.10, MMP and C17 having amino acid sequences and corresponding nucleotide sequences as set forth in <400>1, <400>3, <400>5, <400>7, <400>9 respectively.

Accordingly, another aspect of the present invention provides a polypeptide comprising an amino acid sequence selected from <400>2, <400>4, <400>6, <400>8, <400>10 or an amino acid sequence having at least 60% similarity to any one of said sequences.

Yet a further aspect of the present invention provides a polypeptide encoded by a nucleotide sequence selected from <400>1, <400>3, <400>5, <400>7, <400>9 or an nucleotide sequence having at least 60% similarity to any one of said sequences or a nucleotide sequence capable of hybridizing to any one of said sequences under low stringency conditions at 42°C.

Even yet a further aspect of the present invention provides a nucleotide sequence selected from <400>1, <400>3, <400>5, <400>7, <400>9 or an nucleotide sequence having at least 60% similarity to any one of said sequences or a nucleotide sequence capable of hybridizing to any one of said sequences under low stringency conditions at 42°C.

The term "similarity" as used herein includes exact identity between compared sequences at the nucleotide or amino acid level. Where there is non-identity at the nucleotide level, "similarity" includes differences between sequences which result in different amino acids that are nevertheless related to each other at the structural, functional, biochemical and/or conformational levels. Where there is non-identity at the amino acid level, "similarity" includes amino acids that are nevertheless related to each other at the structural, functional, biochemical and/or conformational levels. In a particularly preferred embodiment, nucleotide and sequence comparisons are made at the level of identity rather than similarity. Any number of programs are available to compare nucleotide and amino acid sequences. Preferred programs have regard to an appropriate alignment. One such program is Gap which considers all possible alignment and gap positions and creates an alignment with the largest number of matched bases and the fewest gaps. Gap uses the alignment method of Needleman and Wunsch (19). Gap reads a scoring matrix that contains values for every possible GCG symbol match. GAP is available on ANGIS (Australian National Genomic Information Service) at website http://mel1.angis.org.au.

Reference herein to a low stringency at 42°C includes and encompasses from at least about 1% v/v to at least about 15% v/v formamide and from at least about 1M to at least about 2M salt for hybridisation, and at least about 1M to at least about 2M salt for washing conditions.

Alternative stringency conditions may be applied where necessary, such as medium stringency, which includes and encompasses from at least about 16% v/v to at least about 30% v/v formamide and from at least about 0.5M to at least about 0.9M salt for hybridisation, and at least about 0.5M to at least about 0.9M salt for washing conditions, or high stringency, which includes and encompasses from at least about 31% v/v to at least about 50% v/v formamide and from at least about 0.01M to at least about 0.15M salt for hybridisation, and at least about 0.01M to at least about 0.15M salt for washing conditions. In general, washing is carried out $T_m = 69.3 + 0.41$ (G+C)% (17). However, the T_m of a duplex DNA decreases by 1°C with every increase of 1% in the number of mismatch base pairs (18).

The present invention also provides genetic constructs comprising nucleic acid molecules encoding the *Mycobacterium* antigens as well as cells transformed with same. Examples of such cells include *Mycobacterium* cells, *E. coli,* insect cells, yeast cells, mammalian cells and plant cells.

The term "derivative" includes mutants, fragments and parts of the polypeptide of the present invention including single and multiple amino acid substitutions, additions and/or deletions to the naturally occurring amino acid sequences.

Preferably, the derivative is an antigenic fragment of the subject polypeptide meaning it contains an epitope required for an antibody in the sera of a patient with active pulmonary or extra-pulmonary tuberculosis to bind to the antigenic fragment.

A homologue includes functionally, structurally or stereochemically similar polypeptides from other species of *Mycobacterium* or other genera of bacteria. A homologue as contemplated herein includes a mimotope. The use of mimotopes is quite useful in competing with *Mycobacterium* polypeptide antigens for binding to antibodies. This competition may then be used to determine the concentration of polypeptides.

Analogues and mimetics include molecules which contain non-naturally occurring amino acids and which do not contain amino acids but nevertheless behave functionally the same as the polypeptide. Natural product screening is one useful strategy for identifying analogues

and mimetics. Natural product screening involves screening environments such as bacteria, plants, riverbeds, seabeds, aquatic environments, coral and antarctic or arctic environments for naturally occurring molecules which mimic, agonise or antagonise the function of the *Mycobacterium* polypeptide of the present invention.

Chemical libraries may also be screened for synthetic mimetics, agonists, antagonists or chemical analogues of the subject polypeptides.

Analogues of the subject peptides contemplated herein also include modifications to side chains, incorporation of unnatural amino acids and/or their derivatives during peptide synthesis and the use of crosslinkers and other methods which impose conformational constraints on the peptide molecule or their analogues.

Examples of side chain modifications contemplated by the present invention include modifications of amino groups such as by reductive alkylation by reaction with an aldehyde followed by reduction with $NaBH_4$; amidination with methylacetimidate; acylation with acetic anhydride; carbamoylation of amino groups with cyanate; trinitrobenzylation of amino groups with 2, 4, 6-trinitrobenzene sulphonic acid (TNBS); acylation of amino groups with succinic anhydride and tetrahydrophthalic anhydride; and pyridoxylation of lysine with pyridoxal-5-phosphate followed by reduction with $NaBH_4$.

The guanidine group of arginine residues may be modified by the formation of heterocyclic condensation products with reagents such as 2,3-butanedione, phenylglyoxal and glyoxal.

The carboxyl group may be modified by carbodimide activation *via* O-acylisourea formation followed by subsequent derivitisation, for example, to a corresponding amide.

Sulphydryl groups may be modified by methods such as carboxymethylation with iodoacetic acid or iodoacetamide; performic acid oxidation to cysteic acid; formation of a mixed disulphides with other thiol compounds; reaction with maleimide, maleic anhydride or other substituted maleimide; formation of mercurial derivatives using 4-chloromercuribenzoate, 4-chloromercuriphenylsulphonic acid, phenylmercury chloride, 2-chloromercuri-4-nitrophenol

and other mercurials; carbamoylation with cyanate at alkaline pH.

Tryptophan residues may be modified by, for example, oxidation with N-bromosuccinimide or alkylation of the indole ring with 2-hydroxy-5-nitrobenzyl bromide or sulphenyl halides. Tyrosine residues on the other hand, may be altered by nitration with tetranitromethane to form a 3-nitrotyrosine derivative.

Modification of the imidazole ring of a histidine residue may be accomplished by alkylation with iodoacetic acid derivatives or N-carbethoxylation with diethylpyrocarbonate.

Examples of incorporating unnatural amino acids and derivatives during peptide synthesis include, but are not limited to, use of norleucine, 4-amino butyric acid, 4-amino-3-hydroxy-5-phenylpentanoic acid, 6-aminohexanoic acid, t-butylglycine, norvaline, phenylglycine, ornithine, sarcosine, 4-amino-3-hydroxy-6-methylheptanoic acid, 2-thienyl alanine and/or D-isomers of amino acids. A list of unnatural amino acid contemplated herein is shown in Table 1.

TABLE 1

Non-conventional amino acid	Code	Non-conventional amino acid	Code
α-aminobutyric acid	Abu	L-N-methylalanine	Nmala
α-amino-α-methylbutyrate	Mgabu	L-N-methylarginine	Nmarg
aminocyclopropane-carboxylate	Cpro	L-N-methylasparagine	Nmasn
		L-N-methylaspartic acid	Nmasp
aminoisobutyric acid	Aib	L-N-methylcysteine	Nmcys
aminonorbornyl-carboxylate	Norb	L-N-methylglutamine	Nmgln
		L-N-methylglutamic acid	Nmglu
cyclohexylalanine	Chexa	L-N-methylhistidine	Nmhis
cyclopentylalanine	Cpen	L-N-methylisolleucine	Nmile
D-alanine	Dal	L-N-methylleucine	Nmleu

	D-arginine	Darg	L-N-methyllysine	Nmlys
	D-aspartic acid	Dasp	L-N-methylmethionine	Nmmet
	D-cysteine	Dcys	L-N-methylnorleucine	Nmnle
	D-glutamine	Dgln	L-N-methylnorvaline	Nmnva
5	D-glutamic acid	Dglu	L-N-methylornithine	Nmorn
	D-histidine	Dhis	L-N-methylphenylalanine	Nmphe
	D-isoleucine	Dile	L-N-methylproline	Nmpro
	D-leucine	Dleu	L-N-methylserine	Nmser
	D-lysine	Dlys	L-N-methylthreonine	Nmthr
10	D-methionine	Dmet	L-N-methyltryptophan	Nmtrp
	D-ornithine	Dorn	L-N-methyltyrosine	Nmtyr
	D-phenylalanine	Dphe	L-N-methylvaline	Nmval
	D-proline	Dpro	L-N-methylethylglycine	Nmetg
	D-serine	Dser	L-N-methyl-t-butylglycine	Nmtbug
15	D-threonine	Dthr	L-norleucine	Nle
	D-tryptophan	Dtrp	L-norvaline	Nva
	D-tyrosine	Dtyr	α-methyl-aminoisobutyrate	Maib
	D-valine	Dval	α-methyl-γ-aminobutyrate	Mgabu
	D-α-methylalanine	Dmala	α-methylcyclohexylalanine	Mchexa
20	D-α-methylarginine	Dmarg	α-methylcylcopentylalanine	Mcpen
	D-α-methylasparagine	Dmasn	α-methyl-α-napthylalanine	Manap
	D-α-methylaspartate	Dmasp	α-methylpenicillamine	Mpen
	D-α-methylcysteine	Dmcys	N-(4-aminobutyl)glycine	Nglu
	D-α-methylglutamine	Dmgln	N-(2-aminoethyl)glycine	Naeg
25	D-α-methylhistidine	Dmhis	N-(3-aminopropyl)glycine	Norn
	D-α-methylisoleucine	Dmile	N-amino-α-methylbutyrate	Nmaabu
	D-α-methylleucine	Dmleu	α-napthylalanine	Anap
	D-α-methyllysine	Dmlys	N-benzylglycine	Nphe
	D-α-methylmethionine	Dmmet	N-(2-carbamylethyl)glycine	Ngln
30	D-α-methylornithine	Dmorn	N-(carbamylmethyl)glycine	Nasn
	D-α-methylphenylalanine	Dmphe	N-(2-carboxyethyl)glycine	Nglu
	D-α-methylproline	Dmpro	N-(carboxymethyl)glycine	Nasp

	D-α-methylserine	Dmser	N-cyclobutylglycine	Ncbut
	D-α-methylthreonine	Dmthr	N-cycloheptylglycine	Nchep
	D-α-methyltryptophan	Dmtrp	N-cyclohexylglycine	Nchex
	D-α-methyltyrosine	Dmty	N-cyclodecylglycine	Ncdec
5	D-α-methylvaline	Dmval	N-cylcododecylglycine	Ncdod
	D-N-methylalanine	Dnmala	N-cyclooctylglycine	Ncoct
	D-N-methylarginine	Dnmarg	N-cyclopropylglycine	Ncpro
	D-N-methylasparagine	Dnmasn	N-cycloundecylglycine	Ncund
	D-N-methylaspartate	Dnmasp	N-(2,2-diphenylethyl)glycine	Nbhm
10	D-N-methylcysteine	Dnmcys	N-(3,3-diphenylpropyl)glycine	Nbhe
	D-N-methylglutamine	Dnmgln	N-(3-guanidinopropyl)glycine	Narg
	D-N-methylglutamate	Dnmglu	N-(1-hydroxyethyl)glycine	Nthr
	D-N-methylhistidine	Dnmhis	N-(hydroxyethyl))glycine	Nser
	D-N-methylisoleucine	Dnmile	N-(imidazolylethyl))glycine	Nhis
15	D-N-methylleucine	Dnmleu	N-(3-indolylyethyl)glycine	Nhtrp
	D-N-methyllysine	Dnmlys	N-methyl-γ-aminobutyrate	Nmgabu
	N-methylcyclohexylalanine	Nmchexa	D-N-methylmethionine	Dnmmet
	D-N-methylornithine	Dnmorn	N-methylcyclopentylalanine	Nmcpen
	N-methylglycine	Nala	D-N-methylphenylalanine	Dnmphe
20	N-methylaminoisobutyrate	Nmaib	D-N-methylproline	Dnmpro
	N-(1-methylpropyl)glycine	Nile	D-N-methylserine	Dnmser
	N-(2-methylpropyl)glycine	Nleu	D-N-methylthreonine	Dnmthr
	D-N-methyltryptophan	Dnmtrp	N-(1-methylethyl)glycine	Nval
	D-N-methyltyrosine	Dnmtyr	N-methyla-napthylalanine	Nmanap
25	D-N-methylvaline	Dnmval	N-methylpenicillamine	Nmpen
	γ-aminobutyric acid	Gabu	N-(*p*-hydroxyphenyl)glycine	Nhtyr
	L-*t*-butylglycine	Tbug	N-(thiomethyl)glycine	Ncys
	L-ethylglycine	Etg	penicillamine	Pen
	L-homophenylalanine	Hphe	L-α-methylalanine	Mala
30	L-α-methylarginine	Marg	L-α-methylasparagine	Masn
	L-α-methylaspartate	Masp	L-α-methyl-*t*-butylglycine	Mtbug
	L-α-methylcysteine	Mcys	L-methylethylglycine	Metg

L-α-methylglutamine	Mgln	L-α-methylglutamate	Mglu
L-α-methylhistidine	Mhis	L-α-methylhomophenylalanine	Mhphe
L-α-methylisoleucine	Mile	N-(2-methylthioethyl)glycine	Nmet
L-α-methylleucine	Mleu	L-α-methyllysine	Mlys
L-α-methylmethionine	Mmet	L-α-methylnorleucine	Mnle
L-α-methylnorvaline	Mnva	L-α-methylornithine	Morn
L-α-methylphenylalanine	Mphe	L-α-methylproline	Mpro
L-α-methylserine	Mser	L-α-methylthreonine	Mthr
L-α-methyltryptophan	Mtrp	L-α-methyltyrosine	Mtyr
L-α-methylvaline	Mval	L-N-methylhomophenylalanine	Nmhphe
N-(N-(2,2-diphenylethyl) carbamylmethyl)glycine	Nnbhm	N-(N-(3,3-diphenylpropyl) carbamylmethyl)glycine	Nnbhe
1-carboxy-1-(2,2-diphenyl-ethylamino)cyclopropane	Nmbc		

Crosslinkers can be used, for example, to stabilise 3D conformations, using homo-bifunctional crosslinkers such as the bifunctional imido esters having $(CH_2)_n$ spacer groups with n=1 to n=6, glutaraldehyde, N-hydroxysuccinimide esters and hetero-bifunctional reagents which usually contain an amino-reactive moiety such as N-hydroxysuccinimide and another group specific-reactive moiety such as maleimido or dithio moiety (SH) or carbodiimide (COOH). In addition, peptides can be conformationally constrained by, for example, incorporation of C_α and N_α-methylamino acids, introduction of double bonds between C_α and C_β atoms of amino acids and the formation of cyclic peptides or analogues by introducing covalent bonds such as forming an amide bond between the N and C termini, between two side chains or between a side chain and the N or C terminus.

All these types of modifications may also be important to stabilise the subject polypeptide if used in a diagnostic or therapeutic test.

The present invention further contemplates functional equivalents of the subject polypeptides. Functional equivalents may not necessarily be derived from the polypeptides

themselves but may share certain conformational similarities. Alternatively, functional equivalents may be specifically designed to mimic certain physiochemical properties of the polypeptides. Functional equivalents may be chemically synthesised or may be detected following, for example, natural product screening.

Reference to the subject polypeptide from *Mycobacterium* species should be read as including reference to all forms of the polypeptide including, by way of example, isoforms or monomeric, dimeric or multimeric forms or peptide fragments of the polypeptide as well as derivatives, homologues, analogues and functional equivalents thereof.

The polypeptide of the present invention may contain a range of other molecules fused, linked, bound or otherwise associated to the polypeptide such as amino acids, lipids, carbohydrates or other peptides, polypeptides or proteins.

The polypeptides of the present invention may be a purified naturally occurring molecule, produced by chemical synthetic techniques or may be produced by recombinant DNA technology.

The present invention further contemplates a method of isolating a polypeptide from *Mycobacterium* species said method comprising culturing cells of said *Mycobacterium* species in a growth medium to increase the number of cells to a sufficient population, harvesting said cells and subjecting said cells to protein extraction techniques to extract protein from said cells, fractionating the extracted protein and subjecting said protein to binding analysis with antibodies to said *Mycobacterium* species or antigenic portions thereof and isolating the polypeptides to which antibodies interact.

Preferably, the *Mycobacterium* species in *M. tuberculosis.*

Preferably, the growth medium is Lowenstein-Jensen medium.

Preferably, fractionation of total polypeptides from *M. tuberculosis* is conducted by SDS-PAGE.

Preferably, the binding analysis in a Western blot analysis.

The isolated polypeptide bands are then generally subjected to N-terminal, C-terminal or internal amino acid sequencing. Nucleotide probes are then produced and cDNA or genomic libraries screened for genetic sequences encoding the isolated polypeptides.

In a particularly preferred embodiment, the polypeptide of the present invention comprises an N-terminal amino acid sequence substantially as set forth in one of SEQ ID NOs: 1 to 10 or an amino acid sequence having at least about 70% similarity thereto.

The term "similarity" as used herein includes exact identity between compared sequences at the nucleotide or amino acid level. Where there is non-identity at the nucleotide level, "similarity" includes differences between sequences which result in different amino acids that are nevertheless related to each other at the structural, functional, biochemical and/or conformational levels. Where there is non-identity at the amino acid level, "similarity" includes amino acids that are nevertheless related to each other at the structural, functional, biochemical and/or conformational levels. In a particularly preferred embodiment, nucleotide and sequence comparisons are made at the level of identity rather than similarity. Any number of programs are available to compare nucleotide and amino acid sequences. Preferred programs have regard to an appropriate alignment. One such program is Gap which considers all possible alignment and gap positions and creates an alignment with the largest number of matched bases and the fewest gaps. Gap uses the alignment method of Needleman and Wunsch (9). Gap reads a scoring matrix that contains values for every possible GCG symbol match. GAP is available on ANGIS (Australian National Genomic Information Service) at website http://mel1.angis.org.au..

Yet another aspect of the present invention is directed to genetic sequences encoding the polypeptide herein described.

Accordingly, another aspect of the present invention provides an isolated nucleic acid molecule comprising a sequence of nucleotides encoding or complementary to a sequence encoding a polypeptide obtainable from a species of *Mycobacterium* and which polypeptide is immunointeractive with sera from a human, animal or avian species exposed to said species of

Mycobacterium or its relative or antigenic parts thereof but which polypeptide is substantially not immunointeractive with sera from a human, animal or avian species not prior exposed to said species of *Mycobacterium* or its relative or its antigenic parts.

The preferred *Mycobacterium* species in *M. tuberculosis* although the present invention extends to any species of *Mycobacterium* or its relatives.

Preferably, the nucleotide sequence encodes an amino acid sequence substantially as set forth in one of SEQ ID NOs: 1 to 10 or an amino acid sequence having at least about 70% similarity thereto.

The nucleic acid molecule of this aspect of the present invention may be cDNA, genomic DNA or mRNA or cDNA/genomic DNA or DNA/RNA hybrids. The nucleotide sequence may encode the amino acid sequence of the naturally occurring polypeptide or it may encode a mutant, fragment, part or other derivative of the polypeptide. Accordingly, the nucleotide sequence may contain one or more nucleotide substitutions, deletions and/or additions to the naturally occurring sequence.

The nucleotide acid molecule of the present invention may be linear or covalently closed single or double stranded molecules, alone or as part of a genetic construct such as an expression vector and/or purification vector.

Still another aspect of the present invention is directed to antibodies to the subject polypeptides or their derivatives, homologues, analogues, mimetics and functional equivalents thereof. Such antibodies may be monoclonal or polyclonal. Where the derivatives are peptides, these may first need to be associated with a carrier molecule in order to induce antibody formation.

The antibodies of the present invention are particularly useful as therapeutic or diagnostic agents. For example, specific antibodies can be used to assist in screening for polypeptides in immunoassays or used as antagonists to inhibit polypeptide activity under certain circumstances. Techniques for such immunoassays are well known in the art and include, for example, sandwich assays and ELISA. Knowledge of polypeptide levels may be

important for monitoring certain therapeutic protocols.

As stated above, the antibodies may be monoclonal or polyclonal antibodies. Alternatively, fragments of antibodies may be used such as Fab fragments. Furthermore, the present invention extends to recombinant and synthetic antibodies and to antibody hybrids. A "synthetic antibody" is considered herein to include fragments and hybrids of antibodies.

As stated above, specific antibodies can be used to screen for the subject polypeptides. The latter would be important, for example, as a means for screening for levels of polypeptides in a cell extract or other biological fluid or purifying polypeptides made by recombinant means from culture supernatant fluid. The antibodies may also be used to screen for the presence of particular *Mycobacterium* polypeptides. The presence of *M. tuberculosis* polypeptides, for example, is indicative of tuberculosis.

It is within the scope of this invention to include any second antibodies (monoclonal, polyclonal or fragments of antibodies or synthetic antibodies) directed to the first mentioned antibodies discussed above. Both the first and second antibodies may be used in detection assays or a first antibody may be used with a commercially available anti-immunoglobulin antibody. An antibody as contemplated herein includes any antibody specific to any region of polypeptide.

Both polyclonal and monoclonal antibodies are obtainable by immunization with the *Mycobacterium* polypeptides either type is utilizable for immunoassays. The methods of obtaining both types of sera are well known in the art. Polyclonal sera are less preferred but are relatively easily prepared by injection of a suitable laboratory animal with an effective amount of polypeptide, or antigenic parts thereof, collecting serum from the animal and isolating specific sera by any of the known immunoadsorbent techniques. Although antibodies produced by this method are utilizable in virtually any type of immunoassay, they are generally less favoured because of the potential heterogeneity of the product.

The use of monoclonal antibodies in an immunoassay is particularly preferred because of the ability to produce them in large quantities and the homogeneity of the product. The

preparation of hybridoma cell lines for monoclonal antibody production derived by fusing an immortal cell line and lymphocytes sensitized against the immunogenic preparation can be done by techniques which are well known to those who are skilled in the art.

Another aspect of the present invention contemplates a method for detecting a subject polypeptide in a biological sample from a subject or culture supernatant flow or other source said method comprising contacting said biological sample with an antibody specific for said polypeptide or its derivative, homologue, analogue, mimetic or chemical equivalent thereof for a time and under conditions sufficient for an antibody-polypeptide complex to form, and then detecting said complex.

The presence of the polypeptide may be accomplished in a number of ways such as by Western blotting and ELISA procedures. A wide range of immunoassay techniques are available as can be seen by reference to US Patent Nos. 4,016,043, 4, 424,279 and 4,018,653. These include both single-site and two-site or "sandwich" assays of the non-competitive types, as well as in the traditional competitive binding assays. These assays also include direct binding of a labelled antibody to a target.

A number of variations of the sandwich assay technique exist, and all are intended to be encompassed by the present invention. Briefly, in one form of forward assay, an unlabelled *Mycobacterium* polypeptide is immobilized on a solid substrate and a sample of animal (e.g. human) sera to be tested brought into contact with the bound molecule. After a suitable period of incubation, for a period of time sufficient to allow formation of a polypeptide-antibody complex, a second antibody specific to animal (e.g. human) immunoglobulin, labelled with a reporter molecule capable of producing a detectable signal is then added and incubated, allowing time sufficient for the formation of another complex of polypeptide-antibody labelled antibody. Any unreacted material is washed away, and the presence of polypeptide specific antibody determined by observation of a signal produced by the reporter molecule or the anti-animal (e.g. human) immunoglobulin. The results may either be qualitative, by simple observation of the visible signal, or may be quantitated by comparing with a control sample containing known amounts of hapten. Variations on the forward assay include a simultaneous assay, in which both sample and labelled antibody are added

simultaneously to the bound antibody. These techniques are well known to those skilled in the art, including any minor variations as will be readily apparent. The method of this aspect of the present invention may readily be adapted for screening for *Mycobacterium* polypeptide by, for example, immobilizing an antibody specific for the polypeptide.

Immobilization of polypeptide or antibody either covalent or passive binding to a solid surface. The solid surface is typically glass or a polymer, the most commonly used polymers being cellulose, nitrocellulose, polyacrylamide, nylon, polystyrene, polyvinyl chloride or polypropylene. The solid supports may be in the form of tubes, beads, discs of microplates, cover slips, slides or any other surface suitable for conducting an immunoassay. The binding processes are well-known in the art and generally consist of cross-linking covalently binding or physically adsorbing the polypeptide or antibody to the solid support. An aliquot of the sample to be tested is then added to the solid phase complex and incubated for a period of time sufficient (e.g. 2-40 minutes or overnight if more convenient) and under suitable conditions (e.g. from room temperature to about 37°C) to allow binding of the polypeptide or antibody to its immobilized ligand. Following the incubation period, the solid phase is washed and dried and incubated with an antibody specific for a portion of the polypeptide or antibody. This antibody is linked to a reporter molecule which is used to indicate the binding of the antibody to its ligand.

An alternative method involves immobilizing the target molecules in the biological sample and then exposing the immobilized target to specific antibody which may or may not be labelled with a reporter molecule. Depending on the amount of target and the strength of the reporter molecule signal, a bound target may be detectable by direct labelling with the antibody. Alternatively, a second labelled antibody, specific to the first antibody is exposed to the target-first antibody complex to form a target-first antibody-second antibody tertiary complex. The complex is detected by the signal emitted by the reporter molecule.

By "reporter molecule" as used in the present specification, is meant a molecule which, by its chemical nature, provides an analytically identifiable signal which allows the detection of antigen-bound antibody. Detection may be either qualitative or quantitative. The most commonly used reporter molecules in this type of assay are either enzymes, fluorophores or

radionuclide containing molecules (i.e. radioisotopes), chemiluminescent molecules colloidal material and precious metals such as gold.

In the case of an enzyme immunoassay, an enzyme is conjugated to the second antibody, generally by means of glutaraldehyde or periodate. As will be readily recognized, however, a wide variety of different conjugation techniques exist, which are readily available to the skilled artisan. Commonly used enzymes include horseradish peroxidase, luciferase, glucose oxidase, β-galactosidase and alkaline phosphatase, amongst others. The substrates to be used with the specific enzymes are generally chosen for the production, upon hydrolysis by the corresponding enzyme, of a detectable colour change. Examples of suitable enzymes include alkaline phosphatase and peroxidase. It is also possible to employ fluorogenic substrates which yield a fluorescent product rather than the chromogenic substrates noted above. In all cases, the enzyme-labelled antibody is added to the antibody-polypeptide complex, allowed to bind, and then the excess reagent is washed away. A solution containing the appropriate substrate is then added to the complex of antibody-polypeptide-antibody. The substrate will react with the enzyme linked to the antibody, giving a qualitative visual signal, which may be further quantitated, usually spectrophotometrically, to give an indication of the amount of polypeptide which is present in the sample. The reporter molecule also extends to use of cell agglutination or inhibition of agglutination such as red blood cells on latex beads and the like.

Alternately, fluorescent compounds, such as fluorescein and rhodamine, may be chemically coupled to antibodies without altering their binding capacity. When activated by illumination with light of a particular wavelength, the fluorochrome-labelled antibody adsorbs the light energy, inducing a state to excitability in the molecule, followed by emission of the light at a characteristic colour visually detectable with a light microscope. As in the EIA, the fluorescent labelled antibody is allowed to bind to the antibody-polypeptide complex. After washing off the unbound reagent, the remaining tertiary complex is then exposed to the light of the appropriate wavelength the fluorescence observed indicates the presence of the polypeptide of interest. Other reporter molecules, such as radioisotope, chemiluminescent or bioluminescent molecules, may also be employed.

The polypeptides of the present invention and antibodies thereto are useful for detecting *Mycobacterium* infection and/or disease or other conditions associated with *Mycobacterium*. The presence of *Mycobacterium* in environmental samples may also be accomplished. In a particularly preferred embodiment, polypeptides derived from *M. tuberculosis* are detected. In this case, the polypeptides are particularly useful in detecting tuberculosis.

Accordingly, another aspect of the present invention contemplates a method for detecting the presence of *M. tuberculosis* such as in a patient suffering from tuberculosis said method comprising contacting a biological sample from a patient or subject with an antibody specific for a polypeptide from said *M. tuberculosis* and detecting a complex between said polypeptide and said antibody.

In an alternative embodiment there is provided a method for detecting the presence of *M. tuberculosis* such as in a patient suffering from tuberculosis said method comprising contacting a sera sample from a patient or subject with a polypeptide from *M. tuberculosis* and detecting a complex between said polypeptide and an antibody in said sera.

The polypeptide-antibody complex may be detected by any convenient means. One particularly useful method is to detect the complex using an anti-immunoglobulin labelled with a reporter molecule such as but not limited to colloidal gold, an enzyme, a radioactive isotope or a fluorescent compound.

In a particularly preferred embodiment, one or more polypeptides from *M. tuberculosis* are immobilized onto a solid support. Sera from a patient suspected of having exposure to *M. tuberculosis* are then brought into contact with immobilized polypeptides(s). After a time sufficient from an immobilized polypeptide-antibody complex to form, unbound material is washed away and an anti-human immunoglobulin labelled with a reporter molecule is brought into contact to bind to human antibodies in the sera of a patient which have bound to the immobilized *M. tuberculosis* polypeptide. The presence of an identifiable signal from the reporter molecule indicates the presence of the polypeptide and of *M. tuberculosis*. This is a particularly convenient means of identifying tuberculosis or a likelihood of tuberculosis or its possible development.

Reference herein to "tuberculosis" includes reference to pulmonary and extra-pulmonary

tuberculosis.

There are many different ways of conducting this assay. For example, an application matrix comprising absorable material such as filter paper and the like may comprise an application region, a *M. tuberculosis* polypeptide region and detection region. In the arrangement, sera from a patient or subject to be tested are applied to the application region and allowed to passage (i.e. "wick") along the application matrix through a region comprising impregnated *M. tuberculosis* polypeptide or its derivatives, homologues, analogues or antigenic equivalents. If antibodies are present in the sera specific for the polypeptide, a complex will form. This complex may be detected directly by the application of an anti-human immunoglobulin antibody labelled with a reporter molecule or the complex may be allowed to migrate into a third region impregnated with anti-human immunoglobulin antibody labelled with a reporter molecule. The identifiable signal produced by the reporter molecule can then be detected in that third region or in a fourth region where the sera-polypeptide-labelled antibody is permitted to concentrate.

In a particularly preferred embodiment, there is provided an assay device for *M. tuberculosis* comprising a solid support having immobilized thereon one or more polypeptides obtainable from *M. tuberculosis* or derivatives, homologues, analogues or antigenic equivalents thereof and a portion of said solid support adapted for receiving a sample from a human subject to be tested wherein said sample would contain an antibody specific for said *M. tuberculosis* polypeptide if said subject has been exposed to *M. tuberculosis* wherein upon contact between the antibody from the subject and the immobilized polypeptide, a complex forms and said complex is detected by an anti-human immunoglobulin labelled with a reporter molecule.

Yet another preferred assay technique comprises applying sera from a subject to be tested to an application matrix and allowing the sera to passage (i.e. "wick") along the matrix and into an area impregnated with recombinant polypeptides from *Mycobacterium* species and in particular *M. tuberculosis*. A complex forms between antibodies in the sera and the polypeptides and these complexes as well as free antibodies and free polypeptides continue to migrate to a region comprising anti-human antibodies labelled a reporter molecule such as, for example, gold. The passaging molecules then enter a region with reduced pore size such as an area containing nitrocellulose. The molecules which are not part of a complex pass through this region whereas complexes of antibodies and polypeptides tend to concentrate as a band in

front of the region with reduced pore size (e.g. nitrocellulose region). If the label is gold the line of complexes is pink or like colour or black. If silver stained or blue when the label is coloured latex particles.

Regardless of the assay procedure, and whether or not "wicking" is involved, one particularly useful procedure for detecting antibody-polypeptide interactivity is through electronic means such as described in US Patent No. 5,580,794.

All such electronic detection means are contemplated for use in accordance with the present invention. For example, interaction between certain molecules may lead to the production of an electrical signal which in turn, *via* a signal processor, correlates with the amount of interaction of amount of certain components of an interaction.

The present invention extends to the detection of a single type or species of *Mycobacterium* polypeptide as well as to the detection of a combination of *Mycobacterium* polypeptides. The detection of combinations of antigens may be accomplished, for example, by using a multiple array of antibodies.

The identification and isolation of the *Mycobacterium* species polypeptide of the present invention further permits the development of therapeutic protocols for generating, for example, an immune response directed to *Mycobacterium* species. Preferably, the *Mycobacerium* species is *M. tuberculosis.*

Accordingly, the present invention contemplates a composition comprising one or more polypeptides for *Mycobacterium* species or a derivative, homologue, analogue, mimetic or chemical equivalent thereof and one or more pharmaceutically acceptable carriers and/or diluents. These components are referred to as the "active ingredients". Preferably, the polypeptides are from *M. tuberculosis* and the composition is capable of inducing an immune response against *M. tuberculosis*.

The compositions suitable for injectable use include sterile aqueous solutions (where water soluble) and sterile powders for the extemporaneous preparation of sterile injectable solutions. It must be stable under the conditions of manufacture and storage and must be

preserved against the contaminating action of microorganisms such as bacteria and fungi. The carrier can be a solvent or dispersion medium containing, for example, water, ethanol, polyol (for example, glycerol, propylene glycol and liquid polyethylene glycol, and the like), suitable mixtures thereof, and vegetable oils. The preventions of the action of microorganisms can be brought about by various antibacterial and antifungal agents, for example, parabens, chlorobutanol, phenol, sorbic acid, thimersal and the like. In many cases, it will be preferable to include isotonic agents, for example, sugars or sodium chloride. Prolonged absorption of the injectable compositions can be brought about by the use in the compositions of agents delaying absorption, for example, aluminum monostearate and gelatin.

Sterile injectable solutions are prepared by incorporating the polypeptide or other active compounds in the required amount in the appropriate solvent with various of the other ingredients enumerated above, as required, followed by filtered sterilization. In the case of sterile powders for the preparation of sterile injectable solutions, the preferred methods of preparation are vacuum drying and the freeze-drying technique which yield a powder of the active ingredient plus any additional desired ingredient from previously sterile-filtered solution thereof.

Pharmaceutically acceptable carriers and/or diluents include any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents and the like.

The principal active ingredient, i.e. the polypeptide, will be present in the composition in an amount effective to induce an immune response. The composition may permit, for example, 0.01 μg to about 2000 mg/kg body weight.

The pharmaceutical composition may also comprise genetic molecules such as a vector capable of transfecting target cells where the vector carries a nucleic acid molecule capable of modulating expression of genes encoding a polypeptide from *Mycobacterium* species. The vector may, for example, be a viral vector.

The present invention further contemplates the use of a polypeptide from *Mycobacterium* species such as *M. tuberculosis* or a derivative, homologue, analogue, mimetic or chemical equivalent thereof in the manufacture of a medicament for the treatment of *Mycobacerium* infection such as tuberculosis.

The present invention is further described by the following non-limiting Examples.

EXAMPLE 1

Extraction of *M. tuberculosis* total protein

Mycobacterium tuberculosis cells (ATCC 27294) were cultured in BBL MycoFlask containing Lowenstein-Jensen medium at 37°C with 10% v/v CO_2. After 2 weeks, the confluent cells were harvested, washed and resuspended in an equal volume of MilliQ H_2O. The cell suspension was heated to 90°C for 2h after which it was frozen at -20°C overnight. Thawed cells were sonicated for 2-3min and pelleted at 14,000rpm for 10min. Extraction of total protein was performed in 8M urea (equal ratio of weight of cells to volume of 8M urea). The cell suspension was vortexed at room temperature for 20 min heated at 90°C for 2min. Insoluble cellular debris was pelleted at 14,000rpm for 10min and the supernatant containing the extracted total protein was kept at -20°C until further use.

EXAMPLE 2

SDS-PAGE analysis and immunological analysis

The total protein extract from M. tuberculosis was fractionated on a 7.5% w/w SDS-PAGE (10) and transferred onto a nitrocellulose membrane by the conventional western blot method (11). Strips containing the Western blotted *M. tuberculosis* total proteins were immunoscreened with pooled sera from 9 patients having active tuberculosis (TB) and pooled sera from 7 normal non-infected individuals, respectively. Detection was carried out using the goat anti-human Ig conjugated with alkaline phosphatase (Harlan Sera lab,UK).

EXAMPLE 3

N-terminal sequencing of *M. tuberculosis* bands

Several individual protein bands (Mwt ranging from 10 to 160 kDa), which reacted positively in the immunoscreening, were excised from a preparative 7.5% w/v SDS-polyacrylamide gel, and concentrated on a long stacking gel (7cm of 4% w/v stacking gel, 5cm of 10% w/v resolving gel). After concentration, the protein bands were blotted onto a PVDF membrane and subsequently stained with Coomassie Brilliant Blue R-250. The stained protein bands were then excised from the membrane and used for N-terminal microsequencing. In addition, some of the protein bands were also blotted onto nitrocellulose membrane to repeat immunoscreening using the same pooled sera samples as previously described.

EXAMPLE 4

Screening the *Eco*R1 lambda ZAP phage expression library of M. tuberculosis genomic DNA

An expression library of *Eco*R1 restricted genomic DNA of *M. tuberculosis* was constructed in lambda ZAP Phage expression vector (according to the protocol by Stratagene (12)). The resultant library have 98% of recombinants ($2X10^6$pfu/μg arms) and insert sizes ranging from 0.7-2kb, observed in excised recombinant plasmids restricted with *Eco*R1 restriction enzyme. A lawn of XL1-MRF' cells infected with about $2x10^4$ pfu of the phage stock was prepared on a 150 mm plate, and incubated inverted, for 6-7 hr at 42°C. The lawn was then overlaid with a Hybond-C filters, presoaked in 1mM IPTG for induction of protein expression and were incubated at 37°C for 4hr, causing the transfer of expressed TB recombinant proteins from the plaques onto the membrane. The plate and filter were indexed for matching of corresponding plate and filter positions. About 20 plates were prepared for the library and as a negative control, a lawn of host cells infected with $2x10^4$ pfu of the non-recombinant lambda ZAP phage was used instead.

Filters were washed twice in TBST buffer (10mM Tris, ph7.5, 300mM NaCl, 0.005% v/v

Tween 20), blocked in 5% w/v skim milk in TBST, washed again in TBST and used to screen against 4 pooled active TB sera and pooled normal sera, respectively. The pre-absortion regime for the pooled sera was as follows: negative control filters containing proteins from induced lambda ZAP phage vector in the bacteria host was used. Pooled sera (diluted 1:100 in 1% w/v skim milk/TBST) was incubated (15ml/filter) for 2hr at RT after which sera was diluted to 1:200 in 1% w/v skim milk/TBST and transferred to a fresh control filter for overnight preabsorption. Screening was as follow: filters containing the expressed recombinant proteins from the phage library were incubated with pre-absorbed human sera for 2 hr, rocking at RT and washed three times in TBST. Secondary antibody of anti-human Ig - alkaline phosphatase conjugated (diluted 1:1000 in 1% w/v skim milk/TBST) was added and allowed to incubate for 1hr. After a final wash, the detection was by colormetric, using NBT/BCIP substrate. An immunoreactive recombinant clone, C17, was isolated and confirmed in the tertiary screening.

Secondary and tertiary plating: positive plaques were cored out and phage eluted in SM bufffer (13) containing 2% v/v chloroform and replated at about 100-200 pfu on a 82mm plates. The screening steps using pooled sera were repeated to confirm the positive clones. In the tertiary screening 6 positive phage recombinants were obtained and these were subsequently subjected to plasmid excision (12). Restriction enzyme *Eco*R1 digestion indicated that all the clones have a 2kb insert which was later confirmed to be identical by DNA sequencing. The clones were designated as C17 and have a 1.16 kb open reading frame (in frame with the vector ATG initiation codon) coding for a 38 ± 3 kDa protein.

EXAMPLE 5

Cloning and expression of genes for the *M. tuberculosis* antigens

Primers were designed from the N-terminal sequences. Polymerase chain reaction (PCR) was performed using the Advantage®-GC Genomic PCR kit (Clontech), *M. tuberculosis* genomic DNA (extracted as previously described (14)) and synthetic oligonucleotides. The PCR products were cloned into the pGEMT vector (Promega) before subcloning into the pQE30 expression vector (15) (Fig. 1). Expression was carried out in M_{15} *E.coli* cells, induced with 1mM IPTG. The M_{15} cells at 3hr after induction were harvested, and cell

pellet lysed in 8M urea buffer at pH6.5. The expressed recombinant protein contained a 6x histidine tag at the N-terminus which facilitated the purification with the Ni-NTA affinity column. Column washes were carried out in 8M urea buffer at pH 6.5 and pH 5.9 while subsequently elution of recombinant protein was carried out at pH4.5.

Table 2 provides the gene sizes for each TB antigen and the theoretical mass.

TABLE 2

GENE SIZE AND PHYSICAL CHARACTERISTICS OF TB ANTIGENS

Antigen	**Size of gene (kb)**	**Theoretical***	
		Molecular mass	**pI value**
B.4	1.617	55.8	5.12
B.6	1.560	55.0	5.03
B.10	0.903	32.9	4.95
MMP	0.432	16.1	5.00
C17	1.161	37.5	9.43

* obtained using the software "Compute pI/Mwt" from ExPASy homepage, Swiss Institute of Bioinformatics, Geneva

The gene size of each TB antigen and the theoretical molecular mass and pI values as calculated from the respective deduced amino acid sequence. The resultant recombinant proteins will be approximately 1.4 to 1.5-kDa larger than the theoretical molecular mass shown, due to the 6x Histidine tag at the N-terminal.

EXAMPLE 6

SDS-PAGE and Western blot of *M. tuberculosis* recombinant antigens

A total of 27μg of a partially purified recombinant antigen was subjected to a SDS-PAG electrophoresis at 180V for 1hr. The recombinant antigen was transferred from the polyacrylmide gel onto a Hybond-nitrocellulose membrane (Amersham) by Western blot (11), using the BioRad TransBlotter (according to manufacturer's protocol). After transfer, the membrane was blocked in 5% w/v milk/TBST, air dried and stored at 4°C until further use.

EXAMPLE 7

Screening of the recombinant *M. tuberculosis* antigens against active (pulmonary and extra-pulmonary), inactive and normal sera panels

Each membrane was cut into strips (a total of 23 strips can be obtained from each blot) and each strip was used for screening with a serum sample. One strip was used as an internal positive of known serum sample which reacted with the recombinant protein antigen and another was used to probe with the commercially available anti-RGSHis probe (QIAGEN). Sera samples were diluted to 1:100 in 1% w/v milk/TBST. Screening was carried out in tubes individually (2 strips/tube) and 3ml of diluted serum/tubes for 1hr with rocking at room temperature. The strips were then washed 3 times in TBST and were incubated with Goat anti-human Ig alkaline phosphatase conjugated (Harlan Sera lab) for 1hr with rocking at room temperature. The strips were washed 3 times in TBST and allowed to develop in 1ml of NBT/BCIP substrate (BioRad) for 4 mins.

Reactivity of recombinant protein to patient sera was interpreted based on the intensity of band observed, ie. negative, + and 2+; the later two were taken as a positive. Faintly stained bands were scored negative.

Using the above screening procedure, the five recombinant antigens were screened against a total of 85 human sera; 43 were from bacteriologically confirmed tuberculosis patients [23 pulmonary, 20 extra-pulmonary]; 22 inactive samples (with skin PPD tve but smear and

bacteria culture negative); and 20 sera samples of uninfected individuals previously vaccinated with BCG. All sera were stored at -70°C before use.

EXAMPLE 8

Identification of *M. tuberculosis* polypeptides

Immunological analysis of Western blotted *M. tuberculosis* total proteins gave 9 protein bands which reacted with the 9 pooled active sera but not with the 7 pooled normal sera. The respective bands were concentrated on a long stacking gel and excised. Excised protein bands were reactive with the pooled active sera but not with pooled normal sera, thus confirming the authenticity of these excised proteins as initially observed in the primary screening (Fig. 2). These proteins were identified by homology searches against protein sequence databases and the result gave a high percentage of homology to *Mycobacterium* proteins (Fig. 3). Primers for PCR were constructed to isolate gene that codes for proteins which gave the high homology (Fig. 1). B.4, B.6, B.10, C17 and MMP were among the genes in addition to B.5 (16), B.9 and 38 kDa isolated from *M. tuberculosis* genomic DNA.

The QIAGEN expression system was selected by the inventors for cloning and expression of the corresponding genes. This system utilizes the pQE30 vector whereby the expressed protein can be purified through a simple one step affinity chromatography and insoluble recombinant proteins can be purified under denaturation conditions (Fig. 1). Expression of recombinant proteins can be immuno-detected by the commercially available anti-RGSHis. In addition, the 6xHis tag is non-immunogenic and thus the purified recombinant protein can be used directly in a Western blot format for screening against the sera.

From the expression studies, B.4, B.5, B.9, MMP and 38 kDa gave high level of expression whereas B.6, B.10 and C17 expression level was low. All of these recombinant proteins were detected by anti-RGSHis. In addition, most of the recombinant proteins were insoluble except for B.5 and C 17 which was soluble. As such the format of choice for our initial screening was on a Western format.

Results of Western screening and the intensity of band observed on the strip is as shown in

Figure 4. Percentage of reactivity were calculated based on the number of sera which gave positive (+ or 2+ observed on the strip) divided by the number of sera sample screened. Figure 5 shows the percentage of reactivity of recombinant TB antigens against different sera panels. A known 38kDa antigen (7, 8) of *M. tuberculosis* was included in the screening. The gene (GeneBank Accession # M30046) for this antigen was cloned, expressed in pQE30 and partially purified. Also shown are the percentages of reactivity of sera samples detected by a commercially available rapid TB diagnostic kit from ICT (Amrad).

Analysis of the screening result is as shown in Figure 5 and Figure 6. B.6, B.9, B.10, C17, MMP and 38 kDa antigens showed no reactivity to the sera from uninfected individuals whereas B.4 and B.5 reacted to 5% and 25% of this panel respectively. B.4 and B.5 may have some epitopes which are recognised by antibodies present in uninfected animals. All of these recombinant antigens showed some reactivity to sera from the active TB panel, both pulmonary and extra-pulmonary. B.6 (52.2%) and B.10 (26.1%) seems to be specifically reactive to active pulmonary samples whereas MMP (25%) is specific to extra-pulmonary samples. All of the recombinant samples, except for B.5 and have low reactivity (<25%) to the inactive sera panel. This is important because a good seriological diagnostic marker would be one that allow differentiation of normal and individuals having previous infection of TB (inactive) from individuals with active tuberculosis.

Overall, the percentage of reactivity to sera panels increased when more recombinant antigens were included in the combination. This is in accordance with the observation that sensitivity increases with the number of antigens used for screening. Combinations including all recombinant antigens (B.4 + B.5 + B.6 + B.9 + B.10 + C17 + MMP+38kDa) gave a sensitivity of more than 90%. However the reactivity to inactive sera samples was also high (36%). Results indicate that the best combination of antigens to use is one that include B.6, B.10, B.4, MMP and C17 which gives a sensitivity of 60-70% to active sera, both pulmonary and extra-pulmonary. Specificity for this combination is 95% but reaches to 100% if excluding B.4 which as indicated earlier exhibited 5% reactivity to sera from uninfected individuals.

Comparison of reactivity against the different sera panel for the combination of all the

recombinant TB antigens compared to the ICT TB diagnostic kit. The graph shows that the percentage of reactivity for the active sera panel (pulmonary and extra-pulmonary) is higher than that observed for the kit.

Combination of antigens (B.6 + B.10 + MMP + 38 kDa) gave a sensitivity (60-70%) higher than that observed for the ICT kit (50%); the reactivity to inactive panel is comparable to that for ICT (Figure 9). As this is not an optimized assay, the sensitivity and specificity can be increased further using a panel of combined recombinant antigens which includes B.4, B.6, B.10, MMP and C17.

EXAMPLE 9

Determination of nucleotide and amino acid sequences of *Mycobacterium* antigens

Nucleotide sequences and corresponding amino acid sequences were determined for antigens B.4, B.6, B.10, C17 and MMP and are shown in <400>1, <400>3, <400>5, <400>7, <400>9 respectively.

Those skilled in the art will appreciate that the invention described herein is susceptible to variations and modifications other than those specifically described. It is to be understood that the invention includes all such variations and modifications. The invention also includes all of the steps, features, compositions and compounds referred to or indicated in this specification, individually or collectively, and any and all combinations of any two or more of said steps or features.

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